



Reliability & Maintainability (R&M) By Design

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Session 1 Outline

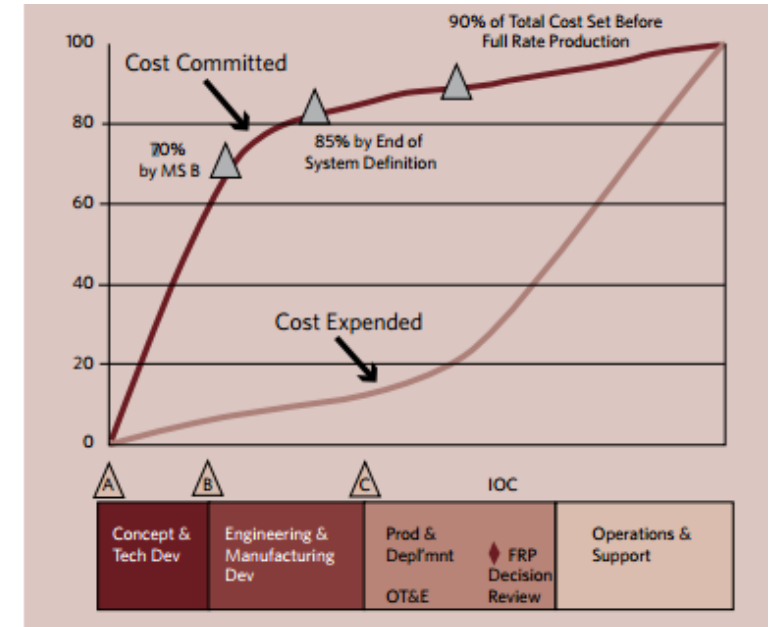
- **R&M Policy: DoD Emphasis**
 - Need for R&M Engineering
 - DoDI 5000.02
 - Essential Elements of an Effective R&M Engineering Program
- **R&M Basic Concepts**
 - R&M Engineering Through the Life-Cycle
 - R&M Engineering Disciplines
 - Performance Requirements
 - Translation of Requirements
 - Program Acquisition Documentation
 - Schedule Considerations
- **DAU Workforce Development**
 - R&M Learning Assets
 - o CLE-301 through CLE-305
 - o ENG-270 RAM-C Rationale Report
 - o ENG-370 Topics in R&M Engineering



Need for R&M Engineering

- **Benefits of an Effective R&M Engineering Program:**

- For the Weapons System/Equipment:
 - o Reduced life-cycle costs
 - o Decreased logistics costs
 - o Increased mission capabilities
 - o Increased readiness
- For the Program Manager and DoD:
 - o Minimize cost increases & schedule delays
 - o Reduce R&M risks associated with Milestone Reviews
 - o Reduce R&M risks associated with Initial Operational Test and Evaluation (IOT&E)

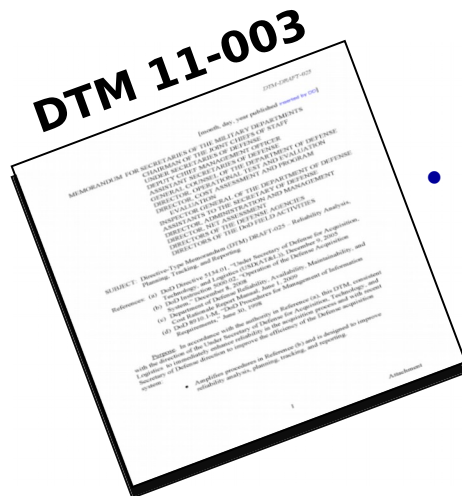
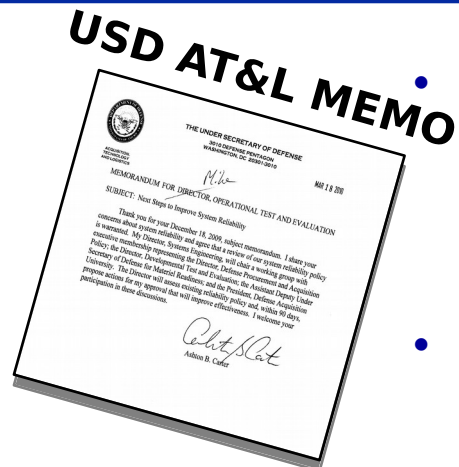
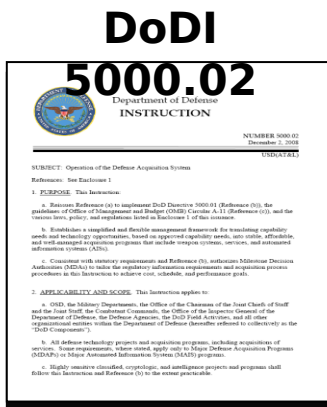


Early application of R&M Engineering is essential to influencing the life-cycle cost of the program



DoDI 5000.02

“Reliability Analysis, Planning, Tracking and Reporting”



- **Impetus for Reliability Policy (2010)**

- Directed by Dr. Carter in response to memo from Director, Operational Test & Evaluation (DOTE)
- DASD(SE) to assess existing reliability policy and propose actions to improve effectiveness

- **DoD Acquisition Policy (DoDI 5000.02 2008)**

- Does not adequately or uniformly consider R&M engineering activities throughout the acquisition process
- Fails to capture R&M planning in new or existing acquisition artifacts to inform acquisition decision making

- **Directive Type Memorandum (DTM) 11-003* (Approved 21 Mar 2011)**

- Amplifies current DoDI 5000.02 by requiring PMs to perform reliability activities
- Institutionalizes planning and reporting timed to key acquisition activities

*** Incorporated into DoDI 5000.02 (2015)**



DoDI 5000.02

Enclosure 3 Overview

- **Engineering activities**

- R&M allocations, block diagrams and predictions
- Failure definitions and scoring criteria
- Failure Mode, Effects and Criticality Analysis (FMECA)
- Built-in Test (BIT) and maintainability demonstrations
- Reliability Growth testing at system/subsystem level
- Failure Reporting, Analysis and Corrective Action System (FRACAS)

- **Preliminary Reliability, Availability, Maintainability - Cost (RAM-C) Report in support of Milestone (MS) A and updated for Dev RFP Release Decision Point, MS B, and MS C**

- Provides early (Pre-MS A) reliability, availability, maintainability and ownership cost feasibility assessments of alternative concepts
 - Includes early formulation of maintenance & support concepts
- Provides an audit trail that documents and supports JCIDS thresholds
- Ensures correct balance between the sustainment metrics (Availability-KPP, Materiel Reliability-KSA, and Ownership Cost-KSA)
- Provides early risk reduction by ensuring requirements are realistic and correct



DoDI 5000.02

Enclosure 3 Overview

- **Reliability Growth Strategy**

- Documents system-level reliability growth curves in the SEP beginning at MS A and updated in the Test & Evaluation Master Plan (TEMP) beginning at MS B
- Establishes intermediate goals for reliability growth curves that will be tracked through fully integrated system-level test and evaluation events until the threshold is achieved
- Requires MS C PMs and Operational Test Agencies to assess reliability growth required to achieve the reliability threshold during Initial Operational Test and Evaluation

- **Tracking and Monitoring**

- Requires PMs to report status of reliability objectives and/or thresholds as part of the formal system engineering review process
- Incorporates Reliability Growth Curves into the Defense Acquisition Executive Summary (DAES) review process



Acquisition Strategy

Section 7.5.10



- **Specify how testing and systems engineering requirements, including life-cycle management and sustainability requirements, have been incorporated into contract requirements.**
 - Identify the engineering activities to be stated in the RFP and required of the contractor to demonstrate the achievement of the reliability and maintainability design requirements.
 - Provide a table to specify how the sustainment key performance parameter thresholds have been translated into reliability and maintainability design and contract specifications.
 - The reliability threshold is often expressed as Mean Time Between Failure (MTBF). Use the appropriate life units (e.g., hours, cycles, etc.). “MTTR” is “mean time to repair;” “N/A” may be entered if an item is not applicable.

Reliability and Maintainability Requirements		
Parameter	Threshold	Contract Specification Requirement
Reliability (e.g., MTBF)		
Maintainability (e.g., MTTR)		



SEP Annotated Outline

R&M Activities

Describe planning and timing to generate R&M artifacts.

R&M Engineering Activity	Planning and Timing
R&M Allocations	
R&M Block Diagrams	
R&M Predictions	
Failure Definitions and Scoring Criteria	
Failure Mode, Effects, and Criticality Analysis (FMECA)	
Maintainability and Built-in Test Demonstrations	
Reliability Growth Testing at the System and Subsystem Level	
Failure Reporting , Analysis, and Corrective Action System (FRACAS)	

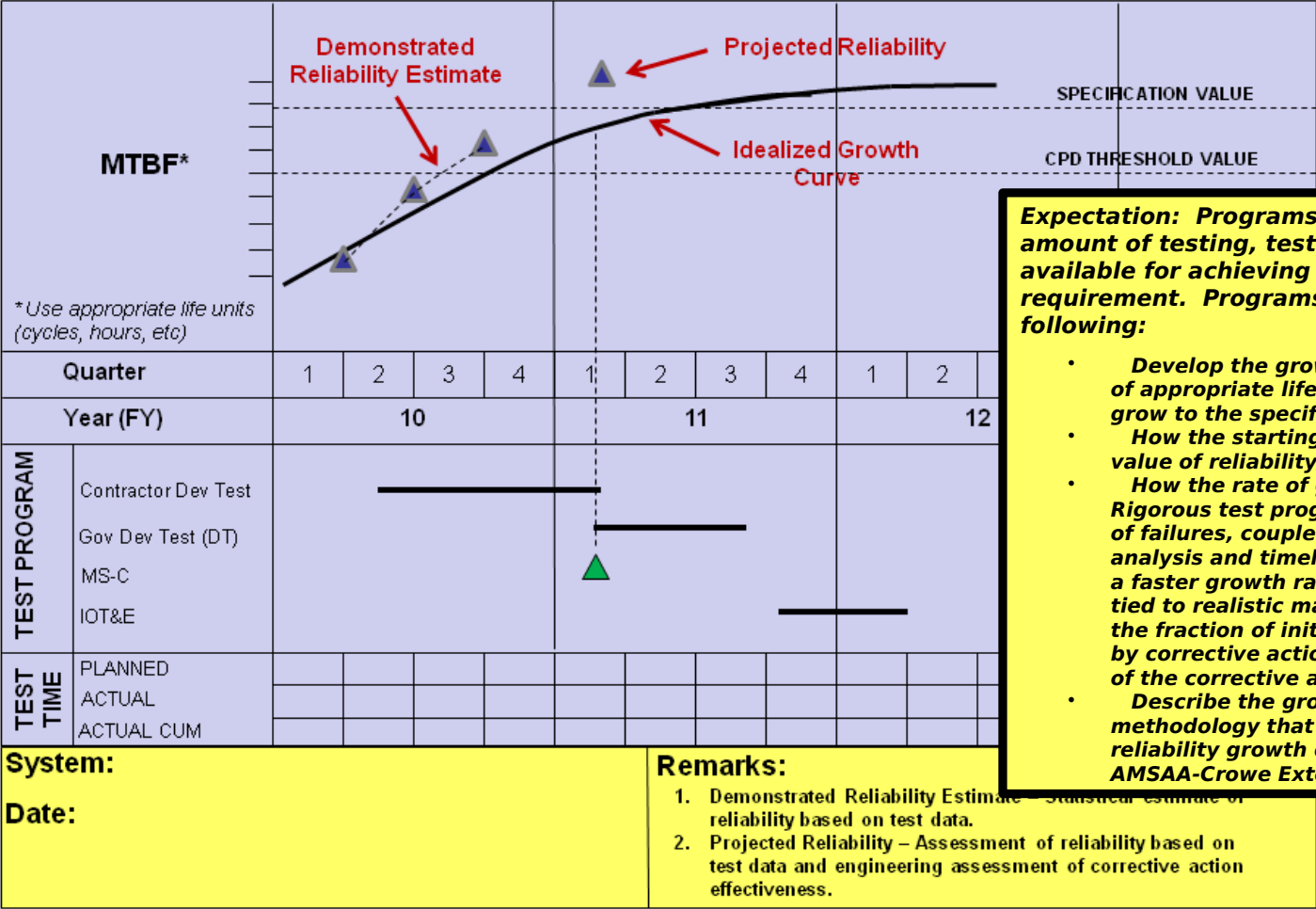
Table 4.6-2 R&M Activity Planning and Timing (mandated) (sample)

- **Expectation:** Programs should understand that the content of the R&M artifacts need to be consistent with the level of design knowledge that makes up each technical baseline.
- **R&M Allocations** - R&M requirements assigned to individual items to attain desired system level performance. Preliminary allocations are expected by SFR with final allocations completed by PDR.
- **R&M Block Diagrams** - The R&M block diagrams and math models prepared to reflect the equipment/system configuration. Preliminary block diagrams are expected by SFR with the final completed by PDR.
- **R&M Predictions** - The R&M predictions provide an evaluation of the proposed design or for comparison of alternative designs. Preliminary predictions are expected by PDR with the final by CDR.
- **Failure Definition and Scoring Criteria** - Failure definitions and scoring criteria to make assessments of R&M contract requirements.
- **FMECA** - Analyses performed to assess the severity of the effects of component/subsystem failures on system performance. Preliminary analyses are expected by PDR with the final by CDR.
- **Maintainability and Built-In Test** - Assessment of the quantitative and qualitative maintainability and Built-In test characteristics of the design.
- **Reliability Growth Testing at the System and Subsystem Level** - Reliability testing of development systems to identify failure modes, which if uncorrected could cause the equipment to exhibit unacceptable levels of reliability performance during operational usage.
- **FRACAS** - Engineering activity during development, production, and sustainment to provide management visibility and control for R&M improvement of hardware and associated software by timely and disciplined



SEP Annotated Outline Reliability Growth Curve

Document the Reliability Growth Curve beginning at MS A, updated at each successive milestone, ...



Expectation: Programs should understand the amount of testing, test schedule and resources available for achieving the specification requirement. Programs should consider the following:

- **Develop the growth planning curve as a function of appropriate life units (hours, cycles, etc,) to grow to the specification value.**
- **How the starting point that represents the initial value of reliability for the system was determined.**
- **How the rate of growth was determined.**
- **Rigorous test programs which foster the discovery of failures, coupled with management-supported analysis and timely corrective action, will result in a faster growth rate. The rate of growth should be tied to realistic management metrics governing the fraction of initial failure rate to be addressed by corrective actions along with the effectiveness of the corrective action.**
- **Describe the growth tracking and projection methodology that will be used to monitor reliability growth during system-level test (e.g., AMSAA-Crowe Extended, AMPM).**



Essential Elements of an Effective R&M Engineering Program



- **Management commitment and attention**
- **Well defined mission oriented requirements**
- **Understand difference between operational and acquisition measures of R&M**
- **R&M design and test activities correctly applied and tailored to all acquisition phases**
- **Realistic schedule associated with R&M disciplines**
- **Sustained reliability growth and maintainability maturation**
- **R&M activities monitored for effective implementation**
- **R&M assessments to inform decisions at key program reviews and milestones**

RELIABILITY & MAINTAINABILITY (R&M) BASIC CONCEPTS

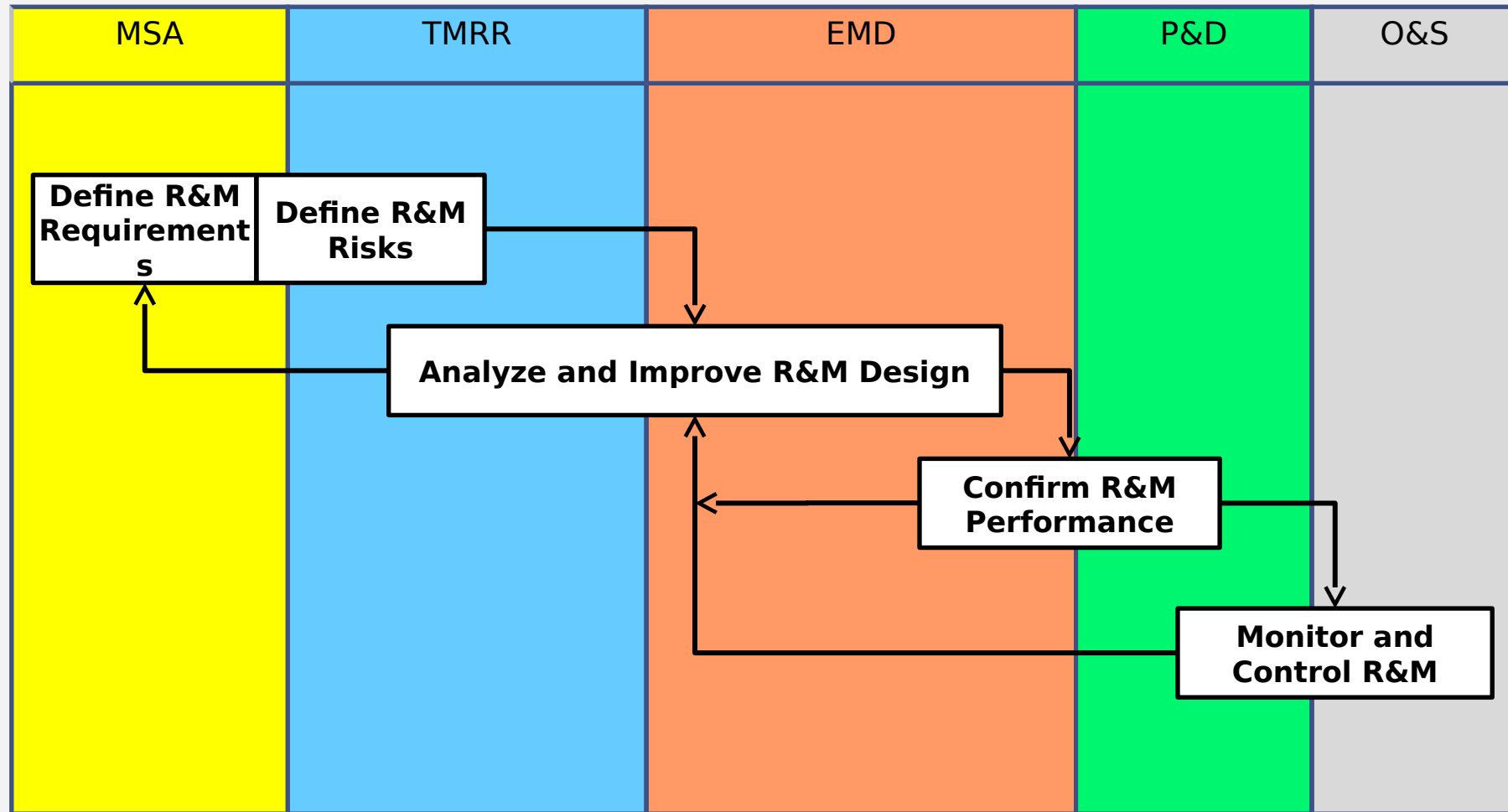
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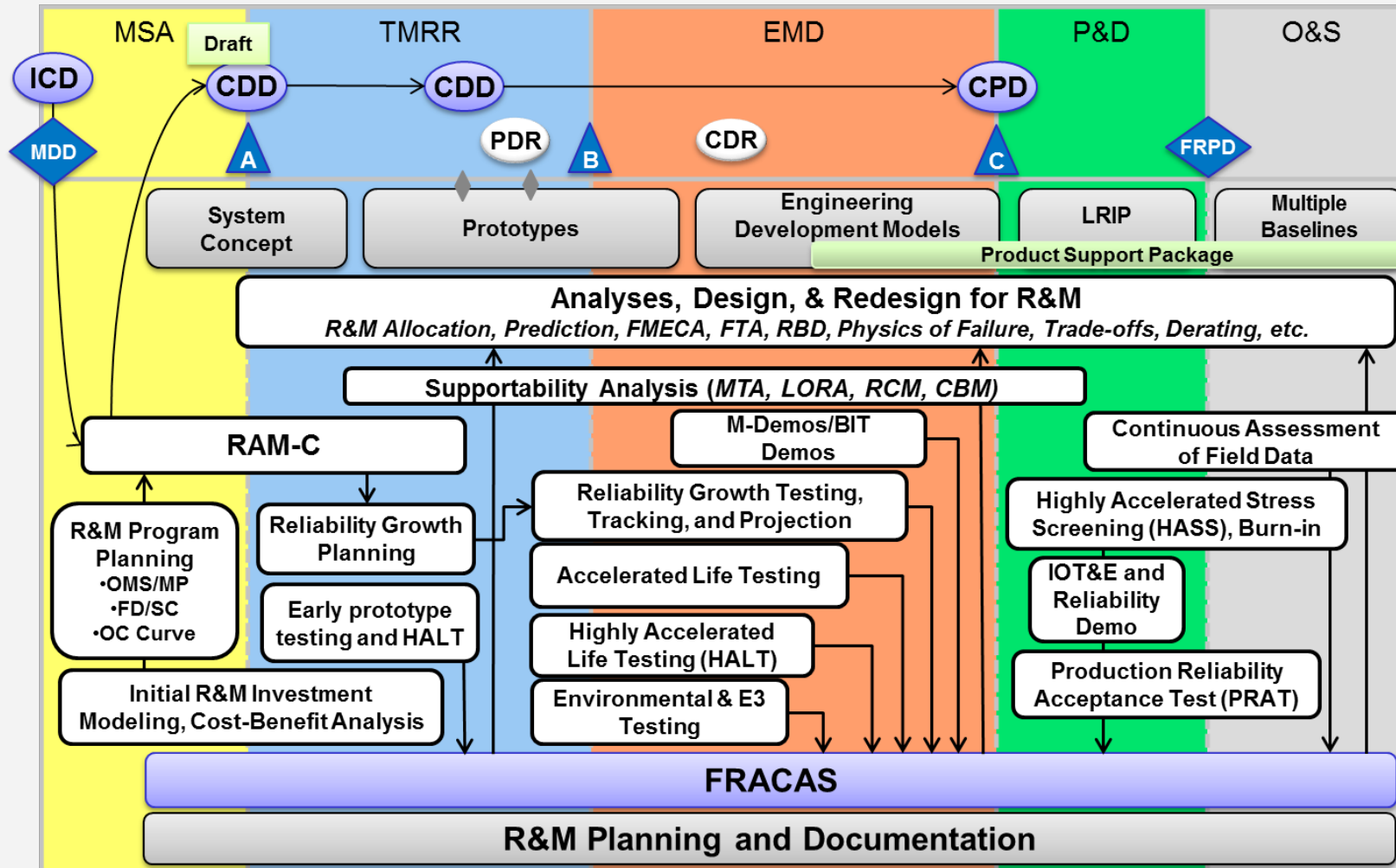


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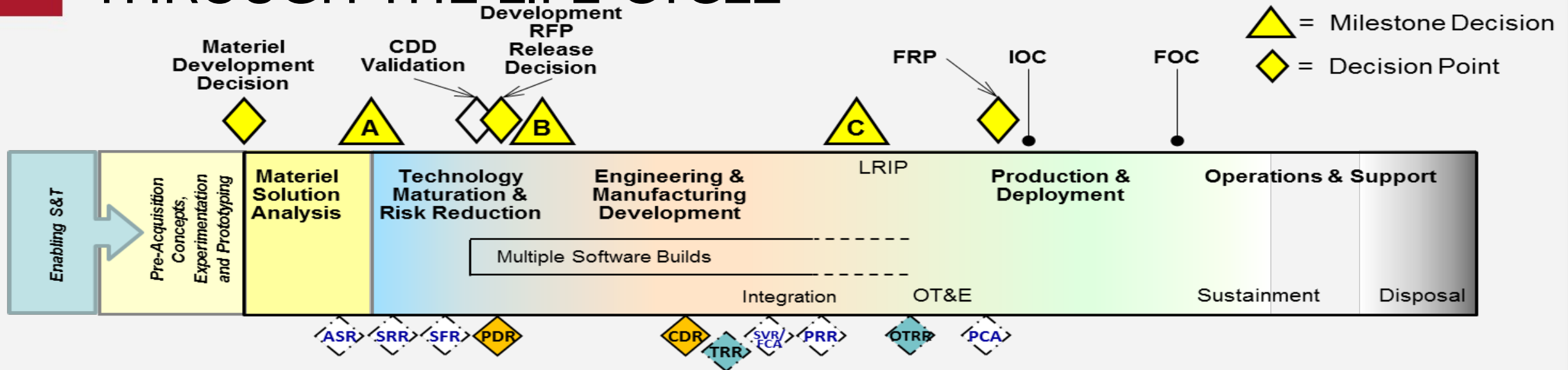
R&M ENGINEERING THROUGH THE LIFE-CYCLE



R&M ENGINEERING ACTIVITIES THROUGH THE LIFE-CYCLE



R&M ENGINEERING ACTIVITIES THROUGH THE LIFE-CYCLE



- Review ICD for R&M objectives
- Develop R&M planning for MSA phase
- Prepare R&M input to MSA phase RFI or study contracts
- Perform R&M requirements analysis
- Review MSA phase RFI or study contracts
- Perform design trade-off studies
- Prepare R&M analysis reports
- Prepare RAM-C Report Summary
- Develop R&M planning for TMRR phase
- Provide R&M input to TEMP
- Provide R&M input to AS
- Provide R&M input to SEP
- Prepare R&M input to RFP for TMRR phase

- Evaluate proposals
- Provide R&M design support
- Develop/review R&M planning for TMRR phase
- Review TMRR phase contract
- Evaluate GFE/COTS
- Perform design trade-off studies
- Conduct design verification tests
- Provide R&M input to Acquisition Strategy
- Develop R&M planning for EMD phase
- Update SEP and RAM-C Report
- Provide R&M input to TEMP for EMD
- Prepare R&M input to RFP for EMD phase
- Conduct preliminary R&M design analyses
- Conduct program review

- Evaluate proposals
- Review EMD phase contract
- Develop/review R&M planning for EMD phase
- Review integrated test plan
- Provide R&M design support
- Conduct program review
- Perform subsystem tests
- Perform system test
- Provide R&M input to Acquisition Strategy
- Perform Government system test
- Develop R&M planning for P&D phase
- Update SEP and RAM-C Report
- Review P&D R&M test plan/input to TEMP
- Prepare R&M input to RFP for P&D phase

- Review P&D phase contract
- Review Integrated Test Plan
- Review R&M Planning for P&D phase
- Provide R&M production support
- Perform Production Reliability Acceptance Test
- Evaluate R&M Program
- Perform System Test
- Perform R&M engineering
- Provide R&M Input to Acquisition Strategy
- Evaluate FRACAS
- Perform Government System Test
- Provide R&M input to TEMP
- Monitor R&M in production

- Develop R&M planning
- Perform R&M engineering
- Conduct R&M demonstrations and tests
- Support ECP procurement
- Support Service operational tests

CONTRACTING TAILORING GUIDANCE

R&M Discipline	MSA	TMR R	EMD	P&D	O&S	New Design "Major" Change	Modified "Minor" Change	NDI/COTS
Program Requirements								
R&M and BIT Program	☑	☑	☑	☑	☑	☑	☑	☑
R&M and BIT Organization		☑	☑	☑		☑	☑	
Subcontractor R&M and BIT Requirements		☑	☑	☑		☑	☑	☑
Trade Studies	☑	☑	☑	☑		☑	☑	☑
Market Survey		☑	☑	☑				☑
Spares Reliability Provisions			☑	☑	☑	☑	☑	
Design Analyses								
Mission Profile Definition	☑	☑	☑	☑		☑	☑	☑
Environmental Effects Analysis		☑	☑	☑		☑	☑	☑
Reliability Math Models, Allocations, and Predictions	☑	☑	☑	☑		☑	☑	☑ (1)
Maintainability and BIT Allocations, Predictions and Analysis	☑	☑	☑	☑		☑	☑	☑ (2)
FMECA and Reliability Critical Items		☑	☑	☑		☑	☑ (4)	☑ (3)
Worst Case / Sneak Circuit Analysis			☑	☑		☑		
Thermal Analysis and Survey			☑	☑		☑	☑	☑
Parts, Material and Processes Program		☑	☑	☑		☑	☑	
Documentation/Data Items	☑	☑	☑	☑	☑	☑	☑	☑
Tests								
Subsystem/Equipment Level Reliability Growth Test		☑	☑	☑		☑		
Subsystem/Equipment Level BIT Assessment Tests			☑	☑		☑		
System-Level Reliability, Maintainability and BIT Demo			☑	☑		☑	☑	☑
Manufacturing Screening			☑	☑		☑	☑	
System Test Monitoring			☑	☑		☑	☑	☑
FRACAS		☑	☑	☑	☑	☑	☑	☑

Notes:

1. Excludes parts count or stress analysis prediction, analysis generally limited to equipment end-item.
2. Maintainability analysis generally limited to equipment end-item.
3. Applicable to the interfaces of COTS/NDI equipment.
4. Applicable to the modified portions and interfaces.

R&M ENGINEERING DISCIPLINES

Activity	Description	Purpose	Benefit
Mission Profile Definition	Provides an accurate representation of actual mission characteristics, pertinent environments, and functions	To develop realistic functional and environmental design requirements for all equipment	Ensures effective design requirements are used, and that ensuing tests use realistic environments
Environmental Study	Detailed evaluation of the environment the system will operate in	Determine the impact the operating environment has on reliability; basis for future test profiles	Establishes system environmental design limits and test profiles
Allocations	Apportions numeric targets to lower level assemblies	Provides IPTs with R&M targets	Management tool to attain top level R&M requirements
Block Diagram and Math Models	Describes relationships of elements that make up the design	Create the necessary models for allocation and predictions	Identifies critical elements and need for redesign or redundancy
Predictions	Numeric R&M analysis of the item	Predicts inherent R&M to determine if requirement can be met	Establishes if design can meet the requirements
FMECA	Analysis of each failure mode to determine the resulting effects on system performance	Identifies critical part and single point failures for redesign opportunity	Systematic identification of failures that negatively impact mission success and safety
FRACAS	A closed loop process that documents failures and establishes trends and corrective actions	Process to identify corrective actions for failures experienced during system development	Essential to mature reliability
Design Reviews	Series of reviews to assess the Contractor's design progress	Forum used to make known current progress of R&M efforts	Program vehicle to raise R&M issues to the highest levels in order to obtain resolution
M and BIT Demo	Exercises the BIT functions on all equipment and systems in the laboratory and on the actual system	Determines whether required M & BIT performance are achieved	Matures M and BIT by finding and correcting problems in both HW and SW

PERFORMANCE REQUIREMENTS

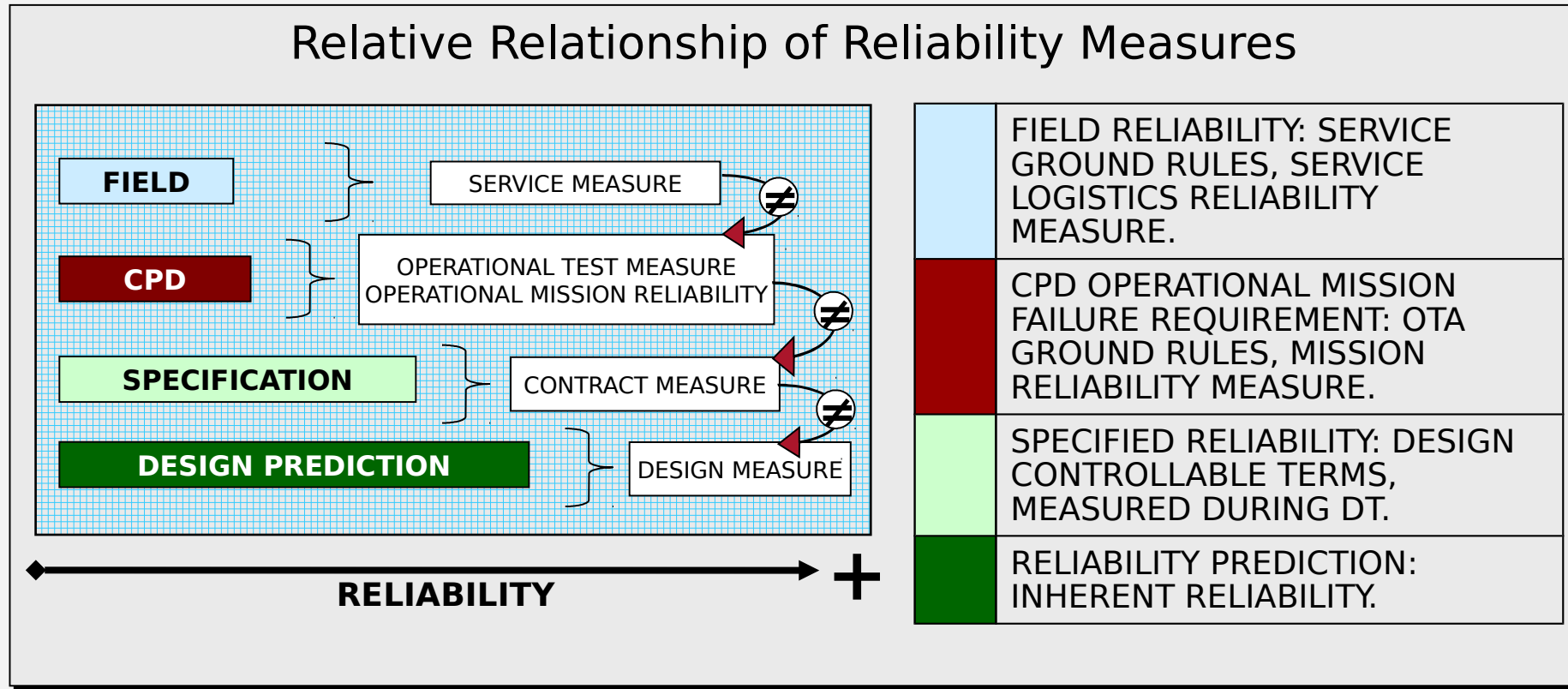
Performance Requirement considerations

- R&M are performance requirements that directly affects readiness, support and total ownership costs
- Contractually specified R&M requirements are traceable to the CDD/CPD
- TEMP R&M OT thresholds = CDD/CPD R&M thresholds

Establishing quantitative requirements

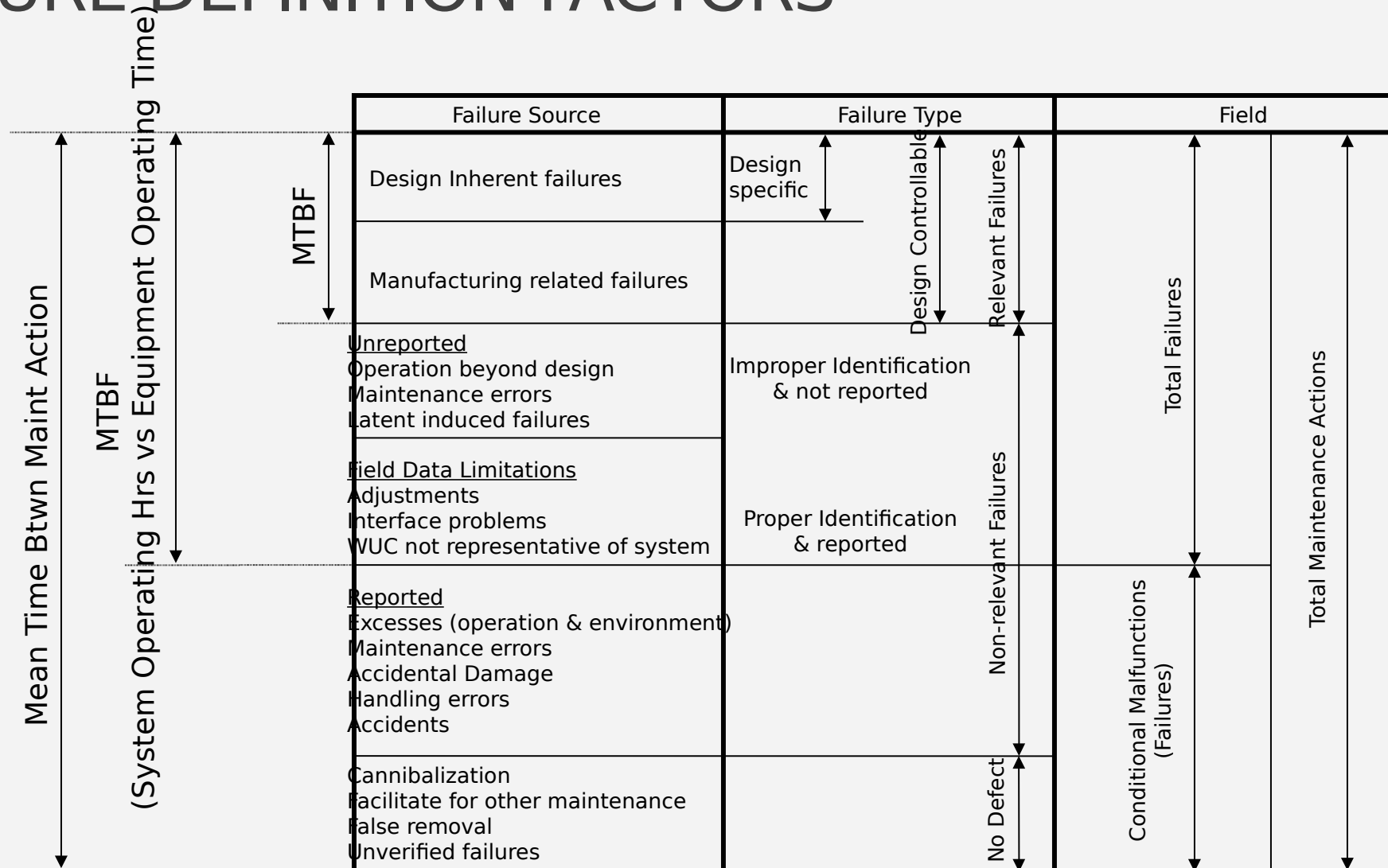
- Unrealistic requirements put program at very high risk
- Translated to contractually specified operational measures of reliability
- Operational Test failure definition scoring criteria need to be worked early-on

TRANSLATION OF REQUIREMENTS



Contract specification requirements should have a good design margin to ensure achieving the stated CDD/CPD thresholds

FAILURE DEFINITION FACTORS



PROGRAM ACQUISITION DOCUMENTATION

R&M inputs are required for:

- AS
 - Describes the R&M engineering strategy for the program
- SEP (including RAM-C Rationale Report)
 - Integrates the R&M engineering activities in the systems engineering program
- TEMP
 - Include an appropriate test strategy for the verification of the program's R&M requirements
 - Include planning and tracking of reliability growth, system and subsystem level R&M demonstration/test events, test support activities and R&M data measurement requirements
- Performance Specification
 - Contains R&M quantitative requirements and verification methods
- Statement of Work (SOW)
 - Includes appropriately tailored R&M engineering activities

SCHEDULE CONSIDERATIONS

It takes finite time to conduct R&M testing, engineer corrective actions, and incorporate them into equipment:

- Incorporate changes in software and hardware between Gov Developmental Test and IOT&E
- Make effective use of applied R&M design/test disciplines (i.e. RDGT, HALT, M-Demos, etc) to sustain reliability growth and maintainability maturation
- Maximize use of production representative units for both Gov DT and IOT&E

No hardware or software design maturity occurs without sufficient time

Gov DT should be the final measure of design and development effort for R&M

SUMMARY

Reliable, maintainable systems are NOT normally produced by routine development

Application of appropriately tailored disciplines are needed to produce reliable and maintainable systems

R&M design disciplines require vigorous pursuit and must be imposed on the contract

R&M analyses can predict equipment behavior needed to reduce risk

Timeliness essential in analysis

R&M by Design and Not by Chance

R&M ENGINEERING CURRICULUM DEVELOPMENT

- **Five R&M Engineering Continuous Learning Modules**
- **ENG-270 RAM-C Rationale Report Course**
- **ENG-370 Topics in R&M Engineering**
- **R&M Engineering Community of Practice**

FIVE R&M ENGINEERING CONTINUOUS LEARNING MODULES

Course Design Document Completed Sep 2015

- CLE-301 R&M Engineering Overview
 - Draft Scripts Developed
- CLE-302 R&M Engineering Planning
 - Draft Scripts Developed
- CLE-303 R&M Engineering Design
 - Scripts in Development
- CLE-304 R&M Engineering in Acquisition
 - Scripts in Development
- CLE-305 R&M Engineering in Program Reviews
 - Scripts in Development

Script Delivery Jul 2016

Storyboard Delivery Sep 2016

Module Programing Jan 2017

ENG-270: RAM-C RATIONALE REPORT DEVELOPMENT COURSE

- **Course Design Document currently under development**
- **Course Design: Online course content followed by graded project**
- **Completion FY17**



ENG-370: TOPICS IN R&M ENGINEERING

- **Two case studies developed by the Systems Engineering Research Center (SERC)**
- **Course delivery method under review**
- **Completion FY17**

R&M ENGINEERING COMMUNITY OF PRACTICE (COP)

- **Development Charter in Development**
- **Sharepoint Design in Development**
- **Stakeholder needs under evaluation**



Reliability & Maintainability (R&M) By Design Questions?

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